A major purpose of the Technical Information Center is to provide the broadest dissemination possible of information contained in DOE's Research and Development Reports to business, industry, the academic community, and federal, state and local governments.

Although a small portion of this report is not reproducible, it is being made available to expedite the availability of information on the research discussed herein.

1

LA-UR -84-1921

NOTICE

PORTIONS OF THIS REPORT ARE ILLEGIBLE. It has been reproduced from the best available copy to permit the broadest possible availability.

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36

TITLE THE DEVELOPMENT OF A 3 TESLA - 10 Hz PULSED MAGNET-MODULATOR SYSTEM

LA-UR--84-1921

DE84 013907

AUTHOR(S) George J. Krausse and K. B. Butterfield

SUBMITTED TO 16th Power Modulator Symposium, Arlington, VA, June 18-20, 1984.

MASTER

DISCLAIMER

Los Alamos Los Alamos National Laboratory
Los Alamos, New Mexico 87545

FORM NO 836 R4
ST NO 2629 5/81

THE DEVELOPMENT OF A 3 TESLA - 10 Hz PULSED MAGNET-MODULATOR SYSTEM

George J. Krausse and K. B. Butterfield
Los Alamos National Laboratory
Los Alamos, NM 87545

Abstract

In order to support the experimental work done at the Los Alamos Meson Physics Facility new instrumentation and data collection systems of advanced design are developed on a regular basis.

Within the instrumentation system for an experiment at LAMPF, "The Photo-Excitation of the H^- Ion Resonances," There exists a need for a pulsed air-core electromagnet and modulator system. The magnet must be capable of producing a field strength of 0 to 3T in a volume of 3.5 cm^3. In addition it must be radiation resistant, have a uniform field, operate in a high vacuum with little or no outgassing, and the physical layout of the magnet must provide minimal azmuthal obstruction to both the ion and laser beams.

The modulator must be capable of producing up to a 15KA pulse with duration of two μs at a maximum repetition rate of 10 Hz. Modulator layout must be of a low inductance design to improve overall system efficiency. Both magnet and modulator must be extremely reliable so that data collection time is not lost during the experiment. This paper describes in detail the development of the system.

Introduction

The design criteria for the pulsed magnet system have, in large part, been determined by the physics of the experiment and the optics of both the ion and laser beams used in the experiment. These factors have required the following specifications for the magnet and the modulator.

The magnet must have a maximum field strength of 3T ± 10% over the volume (3.5cm^3) of interest, see Fig. 1. In addition it must have good high vacuum properties and little or no outgassing at full power. While preserving the integrity of the hi-vacuum system the physical device must be able to move vertically ~10-12 cm so it may be extracted from the beam line. The device must rotate 360° so that θ (see Fig. 1) may be varied thru its full range. This implies that the magnet must provide minimal azumuthal obstruction to both the ion and laser beams.

Magnet Design

An extensive survey of magnet geometries and related construction difficulties was weighed against the design parameters given. This exercise led us to the Helmholtz configuration shown in Fig. 1. The gap (G) was set at 8mm, allowing ample clearance for both ion and laser beams. If one places the current feed

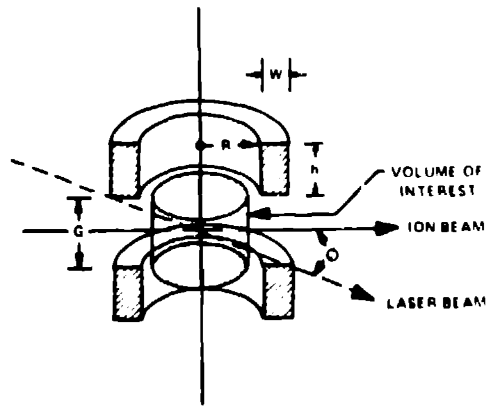

Figure 1. Magnet geometry.

in the shadow of the current return (Fig. 2), θ can be varied thru two 160° sections. By rotating the the assembly 90°, the remaining 40° can be accessed. At this point two computer programs were used to optimize R,W,h and the number of turns for 1T to 3T configurations. Figure 3 shows a cross section of the windings and the dimensions for a 1.0T configuration. The winding materials for the first prototype are shown in Fig. 4. The insulation is reconstructed mica, two layers 0.040mm thick. The conductor is a 5mm wide, 0.127mm thick, strip of copper. Two strips of reconstructed mica shoulder the copper, each three layers thick. The coil was wound on an alumina form and an alumina barrel was slipped over the assembly to hold the windings in place (see Fig. 2). This version of the magnet was found to be unreliable due to breakdown of the mica, leading to arcing between turns.

An improved design, Fig. 5, using Kapton-encapsulated copper windings potted in thermally conducting epoxy was found to be adequate for 1.5T fields. This magnet was then tested with a small SCR Pulser. A field map and a calibration factor were generated. From the field map, Fig. 6, we see the effect of 1/4 extra turn on one coil. This skewed field has since been corrected. The calibration factor for this configuration is 0.98 G/A.

Figure 2. Prototype magnet.

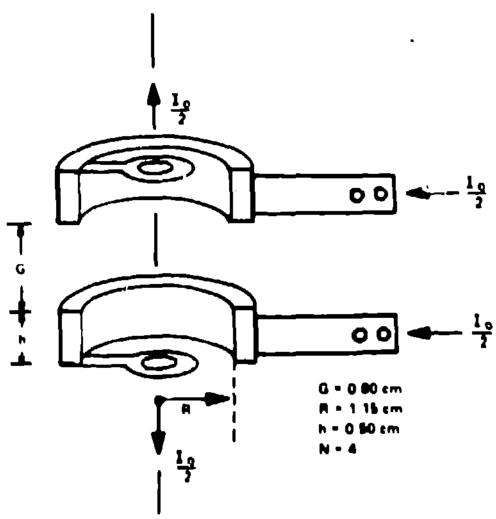

Figure 3. Cross section view of magnet layout.

The inductance of the coil pair is 420nH and the DC coil resistance is 4.6×10^{-3} Ω.

The Modulator

Figure 7 is a circuit diagram of the modulator. In essence the system is a simple RLC circuit with Z_o set such that 15KA peak current could be achieved within the anode limits of the switch (HY-5). This put Z_o = .532 Ω because the magnet inductance (L1,L2) = 420nH. This put the capacitor (c_1-c_6 value at ~1.48μf). Figure 8 shows a cutaway view of the modulator. This configuration was used so that loop inductance could be minimized by removing the magnet and replacing it with a direct short and then fitting

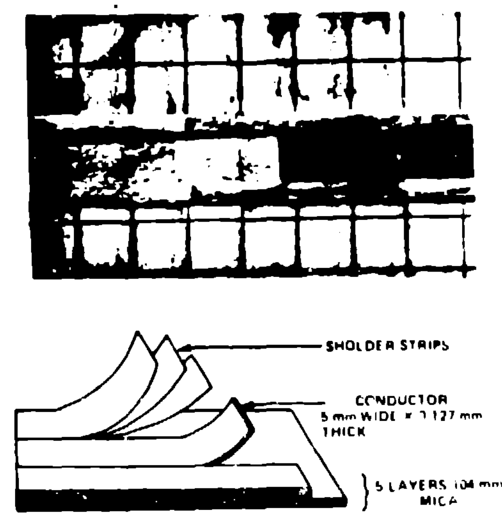

Figure 4. Prototype magnet winding materials.

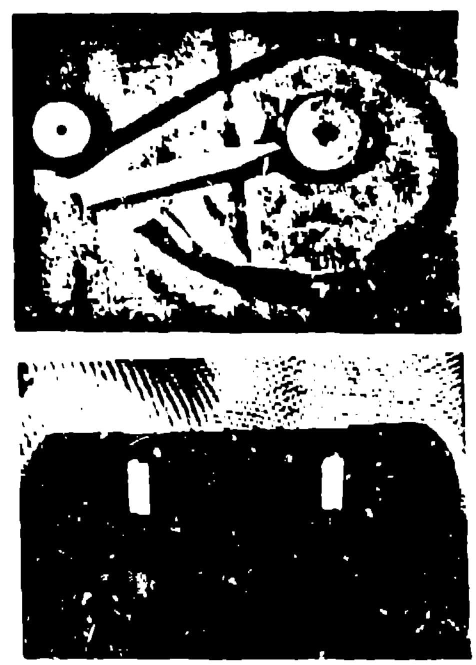

Figure 5. Cross section view of new magnet and winding material.

the current pulse to a theoretical curve. The success of the design was shown by the measured total loop inductance of 64nH. R_1-R_6 are 4.54 Ω each for a parallel combination of .76 Ω which provides a somewhat less then critical damped pulse. The thyratron and the load resistors are water cooled so that the modulator can easily run at the 10kW average power level. The 0.001 Ω Current Viewing Resistor (CVR) is used to monitor peak current and therefore the strength of the B field. Power to the magnet is supplied by coaxial line hi-vacuum feed-through. The modulator was then fitted with the magnet and the system was tested in high vacuum.

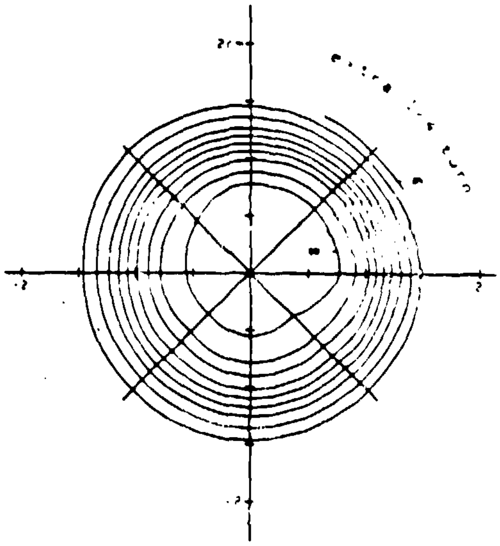

Figure 6. B Field map.

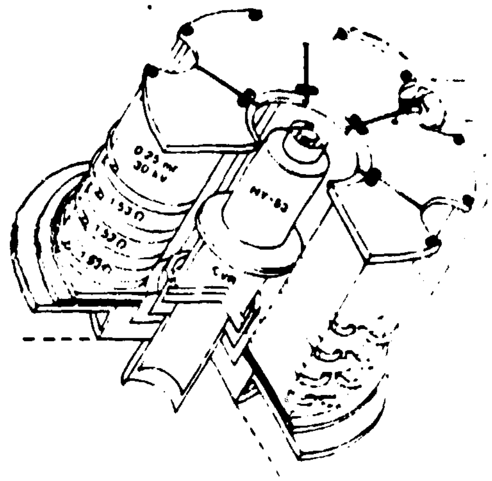

Figure 8. Cross section view of the modulator.

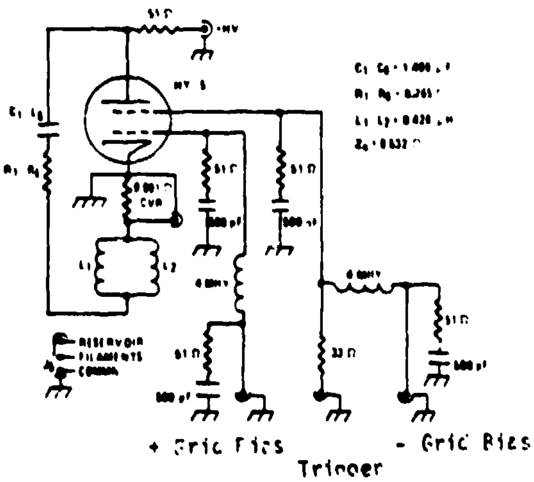

Figure 7. Modulator circuit diagram.

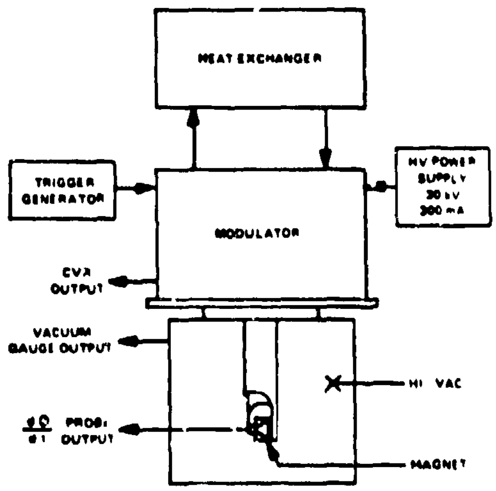

Figure 9. Test setup for magnet and modulator.

Testing

Figure 9 shows the test setup for the magnet and the modulator. High voltage, HV supply current, pulse current and the B field were monitored.

Early on, weak links in the system appeared and in all cases they were related to either coil design or implementation. The modulator has run in an almost flawless manner from the time power was first applied. At this point the modulator has about 3.6×10^7 pulses, has required virtually no maintenance, and has caused no down time. Figure 10 shows a typical current pulse. The 10% to 90% rise time is 500nS and the FWHM is 1.6μS.

The magnet has been a problem that still limits the over all system performance. The problems have been manifold and difficult to solve. The attractive force between the two coils has caused the copper windings to cut the insulation. IR heating and inadequate cooling have caused magnets to run red hot. Local arcing, caused by large L(di/dt) terms, has caused coils to explode.

At this point the problem has been reduced to one of materials research. The insulation used in the magnet windings must have high dielectric strength and yet be thermally conductive. Figure 5 shows a photo of the new magnet assembly. The coil winding is 0.5mm

›per strip 0.127mm thick bonded between two 0.127mm ick kapton strips. The winding is potted in vacuum a thermally conductive epoxy. Figure 5 also shows cross section of a winding. This construction has owed us to run at peak power of ~800J to 1KJ per se, but at these power levels we can only run at a se frequency of ~5HZ, due chiefly to the lack of ling.

Conclusion

Ultimately B fields of >3T and repetition rates HZ will be required. Therefore new cooling systems h greater heat capacities and improved thermal hs are being considered. New coil designs based on ti-layer hybrid technology are being developed. In ition new thyratrons with higher anode voltage its and higher cathode currents than the HY-5 are er consideration.

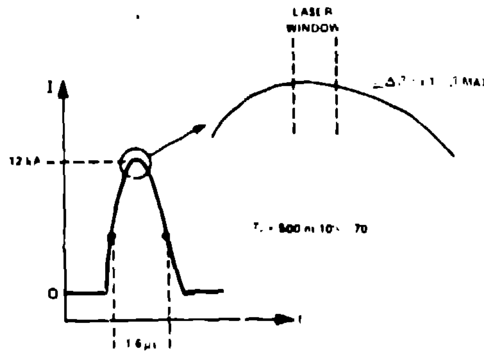

Figure 10. Current pulse.